



# Resource Prospector (RP)

A lunar volatiles prospecting and In-Situ Resource Utilization (ISRU)  
demonstration mission



Briefing to IEEE Robotics and Automation Society

Daniel Andrews, RP PM

2016-07-20

<http://www.nasa.gov/resource-prospector> @NASAexplores

No Export Controlled materials (ITAR/EAR)

# The Hunt for Lunar Volatiles



Clementine (1994):  
*Bi-static radar tests with Arecibo could indicate water-ice in permanently shadowed craters*

Lunar Prospector (1998):  
*Permanently-shadowed polar craters contain elevated Hydrogen levels*

LCROSS/LRO (2009):  
*There is water-ice and other volatiles in the permanently-shadowed regions*

*“Could that Hydrogen be trapped as water-ice?”*

*“How are the volatiles distributed and can we make use of them?”*

RP (2020): “Land and prospect for the water-ice. Experiment with ISRU to extract water from the soil...”

LCROSS not only confirmed presence of water-ice in a permanently-shadowed region, but showed there may be enough to be economically viable.

RP will provide water-ice distribution on human-scales [m-km], and will explore if areas of *temporary sunlight* might also retain water ice, making water potentially much more accessible.

# Evolvable Lunar Architecture Press Conference

2015-07-20



The Top Strategic Risk:  
we don't know exactly  
how much water is in  
the moon or how deep,  
or how plentiful it is.  
This is a key strategic  
issue we need to  
understand... and if  
there is one thing we  
should do soon, it is to  
send soon a resource  
prospector to the  
moon.

*Charles Miller - Study PI &  
President of NexGen Space  
LLC*



Press conference by National Space Society (NSS) and Space Frontier Foundation (SFF) announcing their support for NASA's funding of the newly released NexGen Space study. Study: "Economic Assessment and Systems Analysis of an Evolvable Lunar Architecture that Leverages Commercial Space Capabilities and Public - Private - Partnerships"; NASA funded the \$100K study; Independent review of study occurred 2015-03



# EVOLVABLE MARS CAMPAIGN

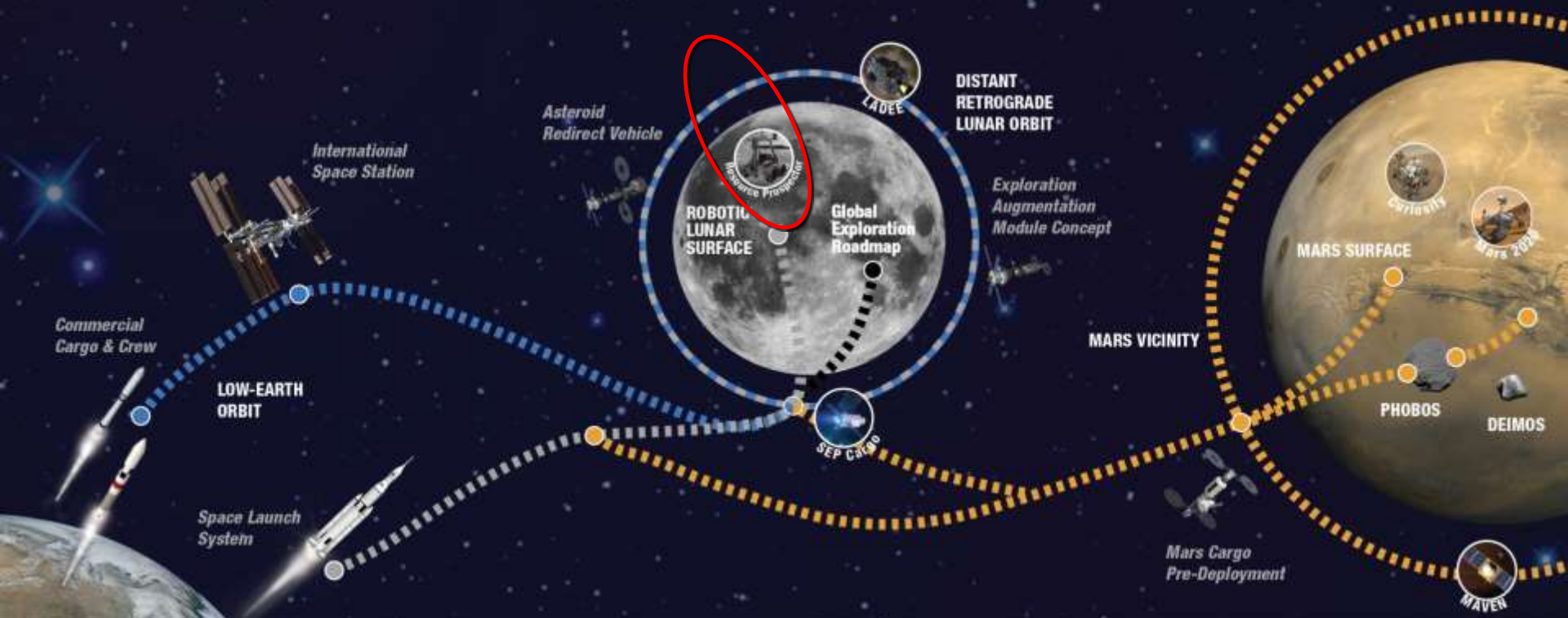
*A Pioneering Approach to Exploration*



EARTH RELIANT

PROVING GROUND

EARTH INDEPENDENT



## THE TRADE SPACE

### Across the Board

Solar Electric Propulsion • In-Situ Resource Utilization (ISRU) • Robotic Precursors • Human/Robotic Interactions • Partnership Coordination • Exploration and Science Activities

### Cis-lunar Trades

- Deep-space testing and autonomous operations
- Extensibility to Mars
- Mars system staging/refurbishment point and trajectory analyses

### Mars Vicinity Trades

- Split versus monolithic habitat
- Cargo pre-deployment
- Mars Phobos/Deimos activities
- Entry descent and landing concepts
- Transportation technologies/trajectory analyses

# RP Mission Animation



# Site Selection Criteria



## Likely subsurface volatiles

- Sustained low subsurface temperatures conducive to volatile retention
- Orbital neutron spectrometer hydrogen signature

## Sufficient daylight illumination

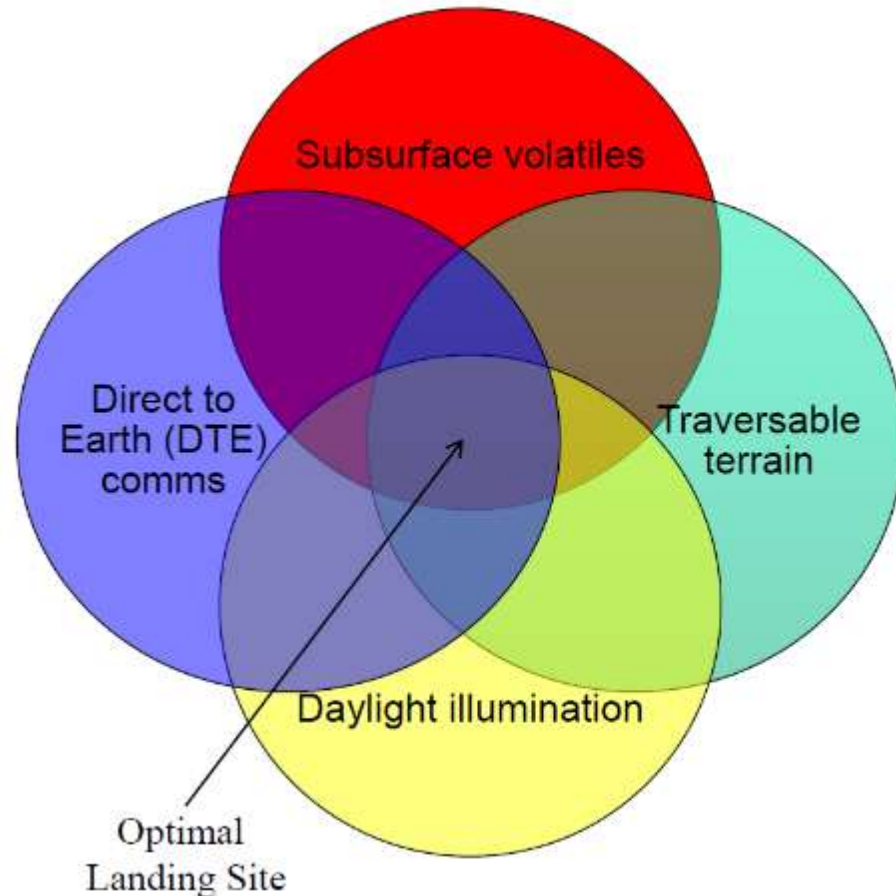
- More than 4 Earth days of solar power for rover operations
- Clement surface temperature for rover survival

## Suitable for Direct to Earth (DTE) communication

- DSN stations clear the horizon

## Traversable terrain

- Slopes < 10 deg
- Limited density of rocks



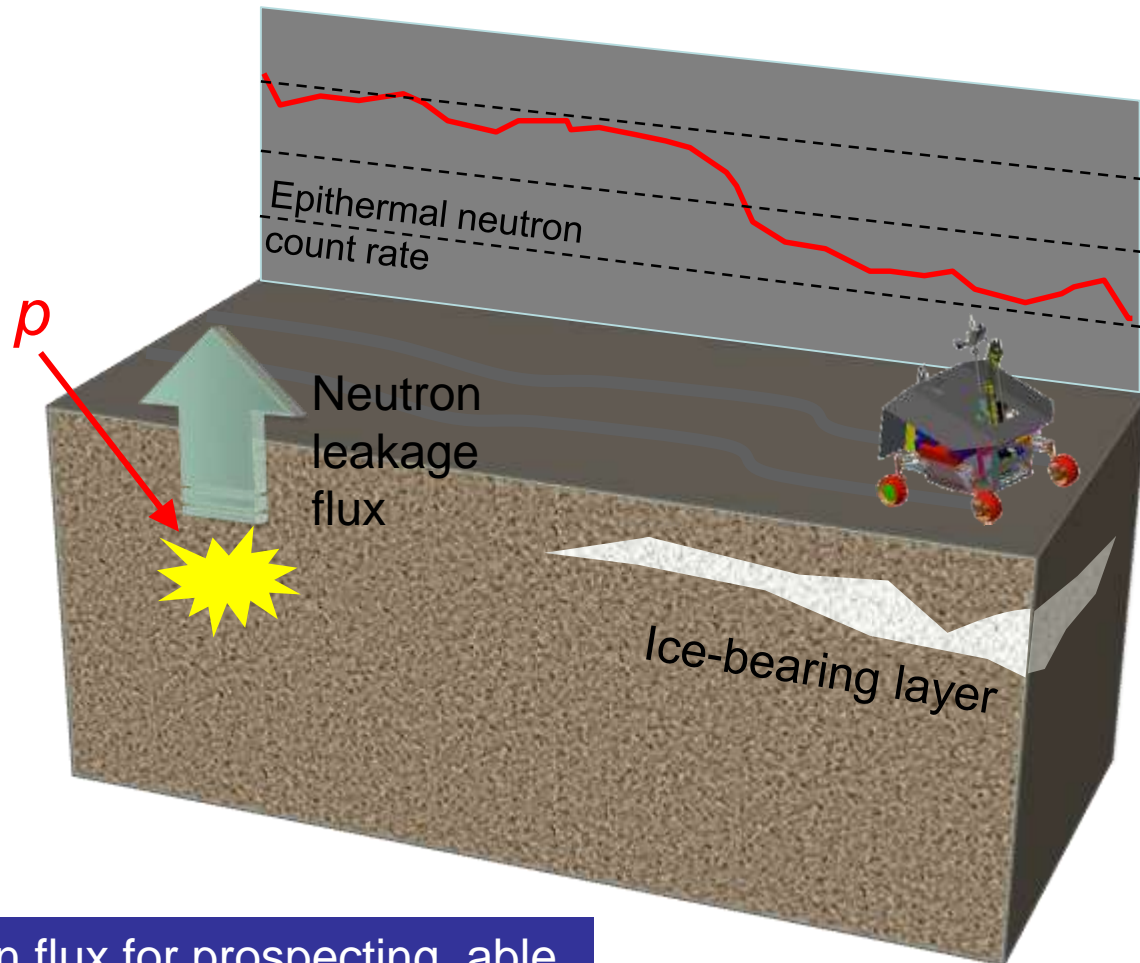
2011-10-18, "RESOLVE Sun & Shadow DRM 2.2", RESOLVE Architecture Team



# NSS Subsurface Hydrogen (Ice) Sensing



- Galactic cosmic rays shatter nuclei in the lunar soil
- The shattered nuclei release neutrons, creating a “flux” of neutrons leaking to space
- Those leaked neutrons tell us about near-subsurface composition
- Variations in that Neutron flux while roving, tell us about the abundance and burial depth of hydrogenous materials in subsurface

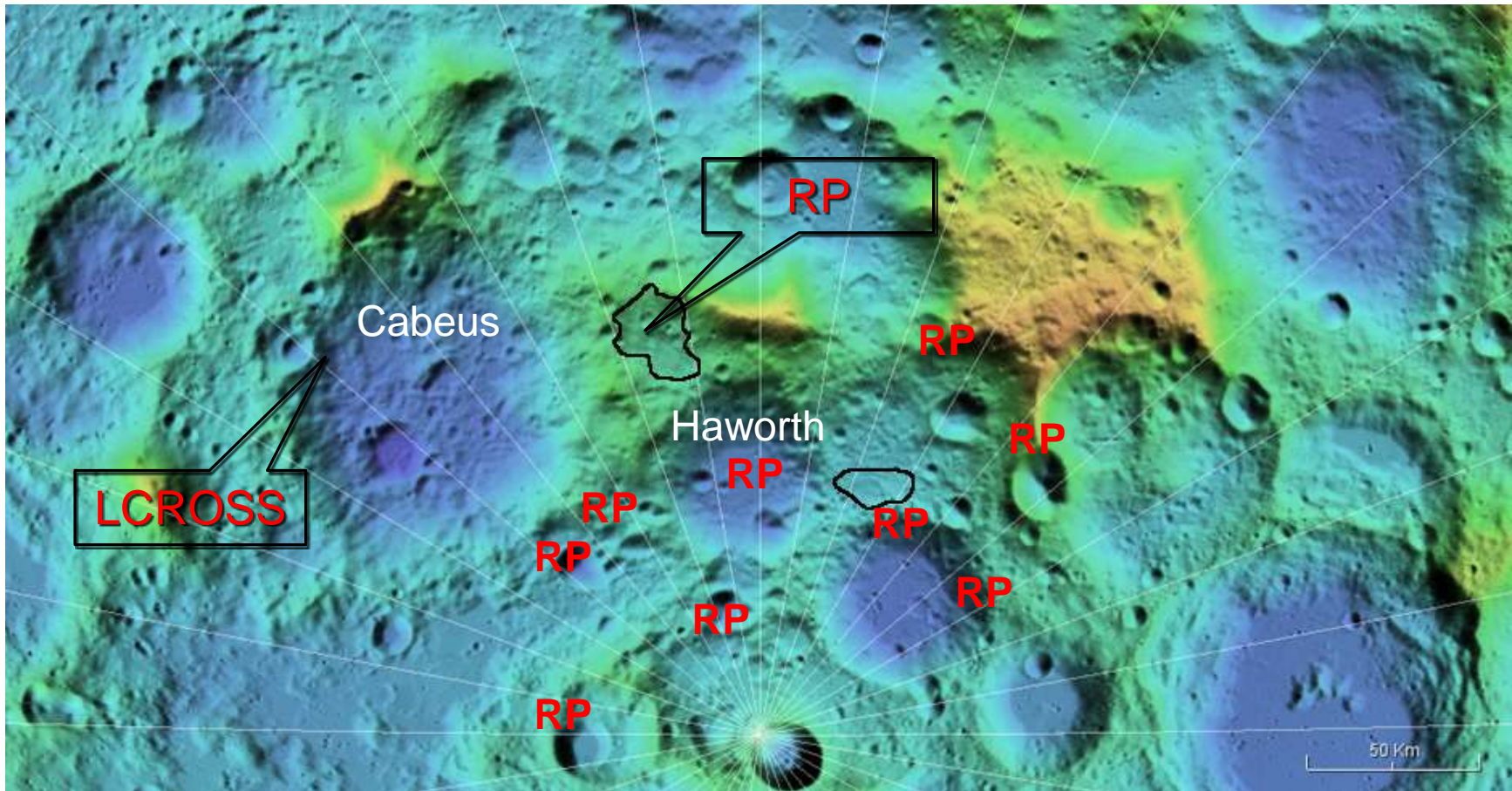


The RP NSS measures neutron flux for prospecting, able to sense hydrogen-bearing materials (e.g. water-ice) up to 1 meter depth, enabling mapping while roving

# Landing sites under discussion



- RP Team is working with candidate partners to optimize landing site
  - Many possibilities exist trading **volatiles concentration**, **terrain**, **lighting**, **Direct-To-Earth Comm**, and **mission duration**







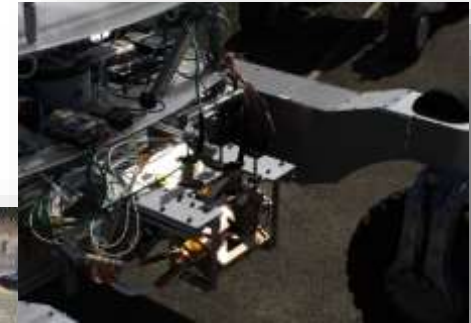
# RP15 Field Testing

# RP Neutron Spectrometer (NSS) & NIR Spectrometer (NIRVSS) field tests (2014-08)



## NSS in the NASA-ARC Roverscape

- The NSS is located on the rover and in front of that is a neutron source holder for Earth testing only (simulating lunar radiation activity)
- The team has driven across rock patches and an ice proxy for testing



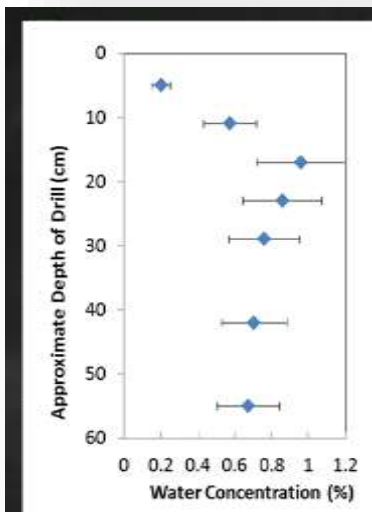
## NIRVSS in the NASA-ARC Roverscape

- The team drove across rock patches and an ice proxy for testing



# RP Drill & NIRVSS testing

2013-09 & 2015-07

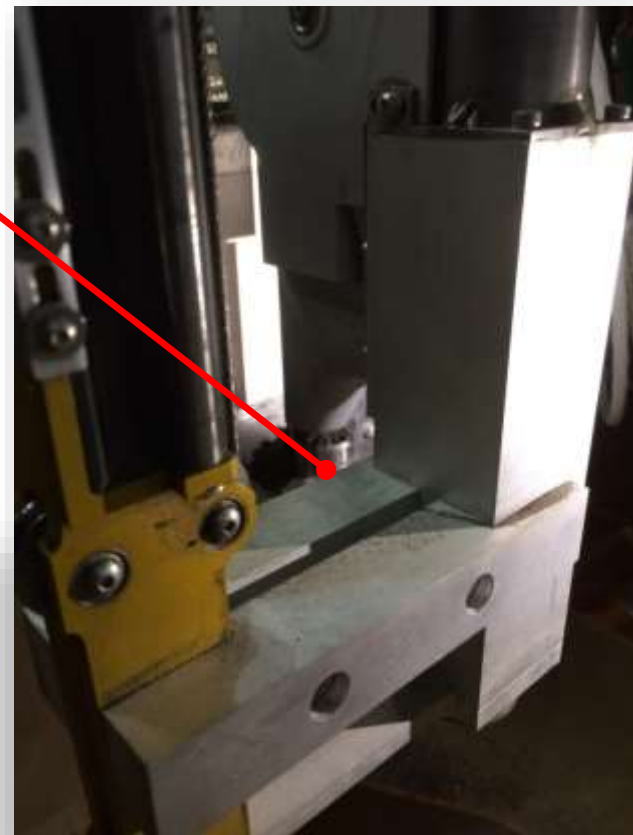


1379085500 Fri 09 13 13

Drill & NIRVSS testing  
in TVAC chamber at  
NASA-GRC (-80°C)



OVEN  
Crucible



RP15 Rover-hosted Drill testing in  
doped simulant tube at NASA-JSC

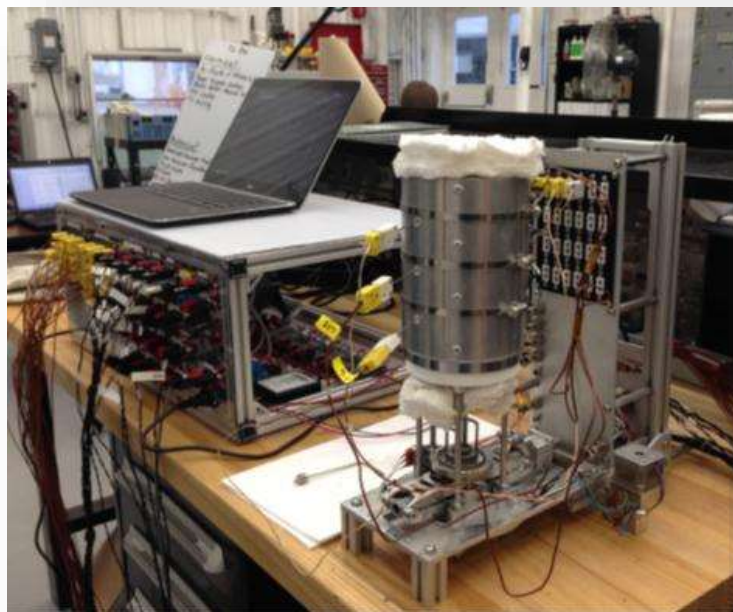


# RP OVEN ETU testing

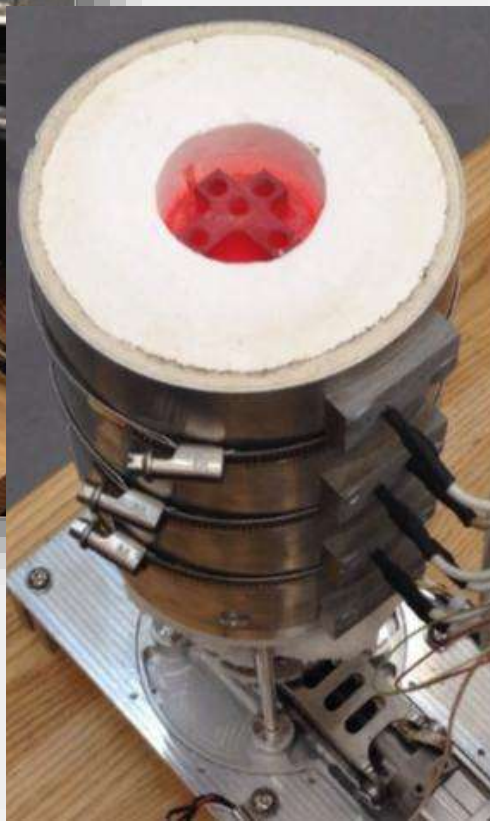
2014-04



- RESOLVE ISRU payload systems undergoing engineering test
  - Subsystem TVAC and vibe testing, drilling in relevant environment, etc



OVEN Reactor Checkout Testing



OVEN Reactor Heater at 700+°C



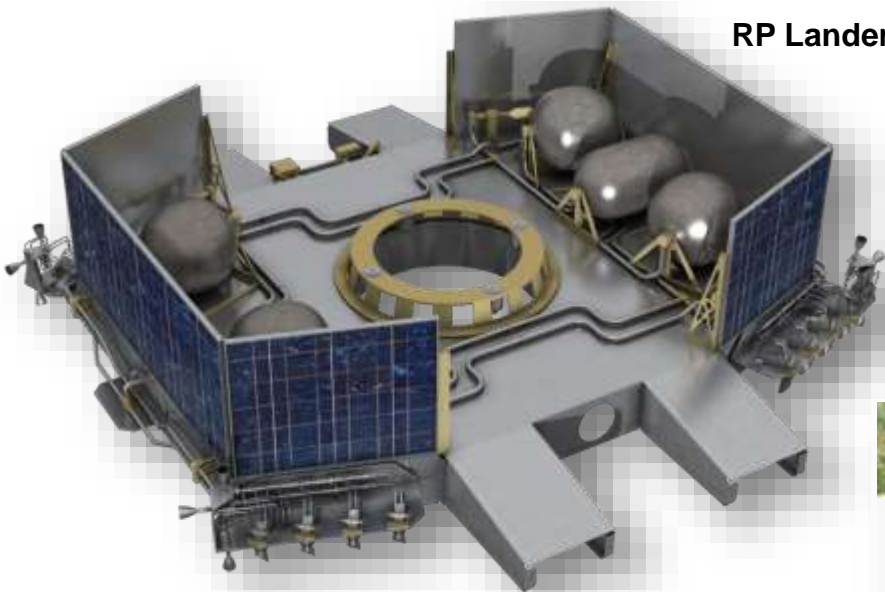
OVEN Reactor Mechanical Assembly

# RP Partnering Lander Concept

2014-05



RP Lander Design



Lander Prototype & Propulsion testbed

- Prototyped a cost-efficient lander
  - Novel aluminum riveted structure concept reduces complexity and cost
  - NASA looking for international partner to provide the lander





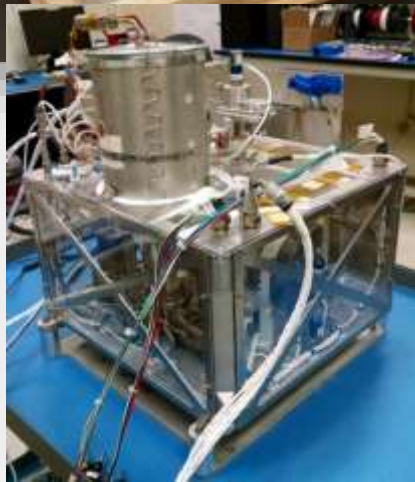
# RP15 Payload Activities

2015-05

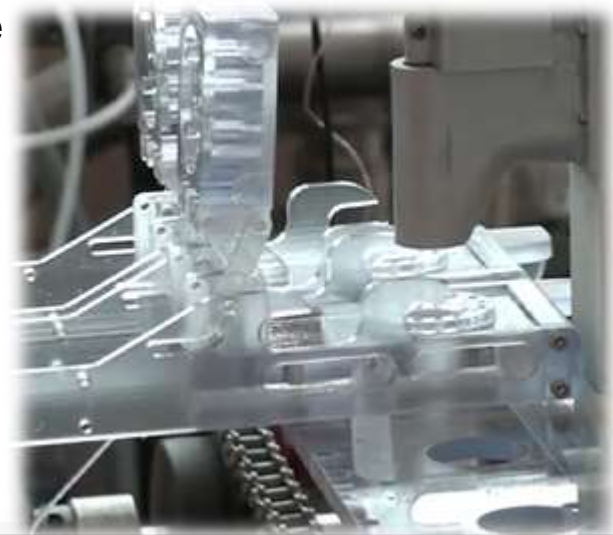


Material capture

Payload & Drill subsystem



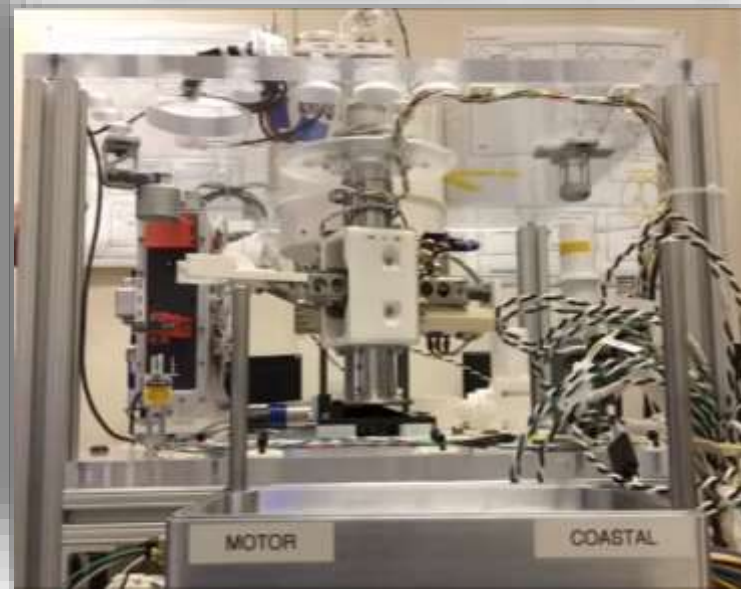
Material capture



Regolith filling the crucible



Crucible processing



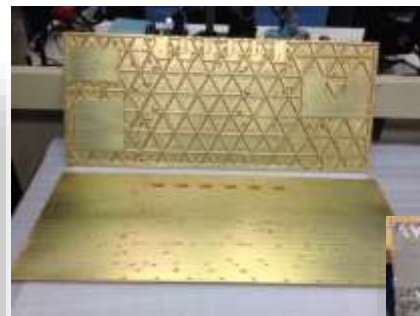


# RP15 Rover Activities

2015-06



## Rover Frame/Chassis



Heat spreaders



Batteries

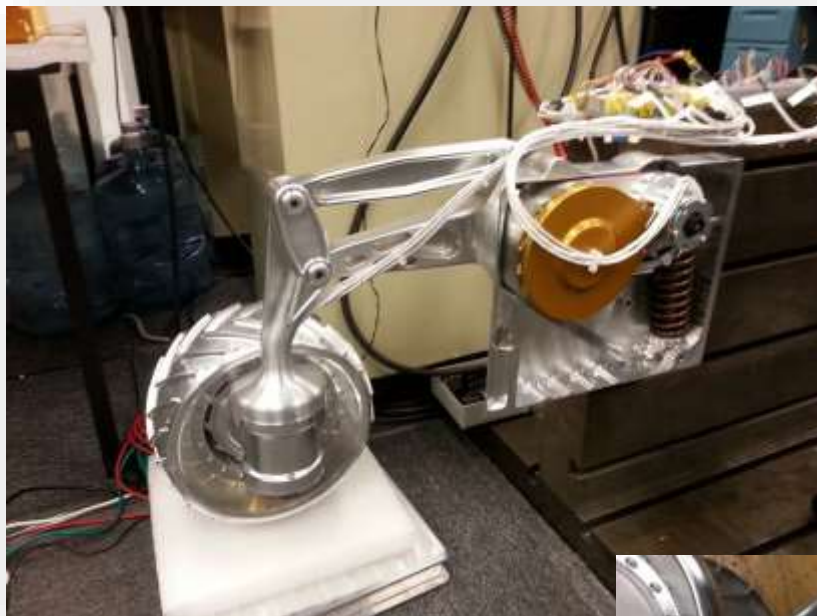


# RP15 Rover Activities

2015-06



## Rover Suspension/Drive Subsystem



Suspension assembly



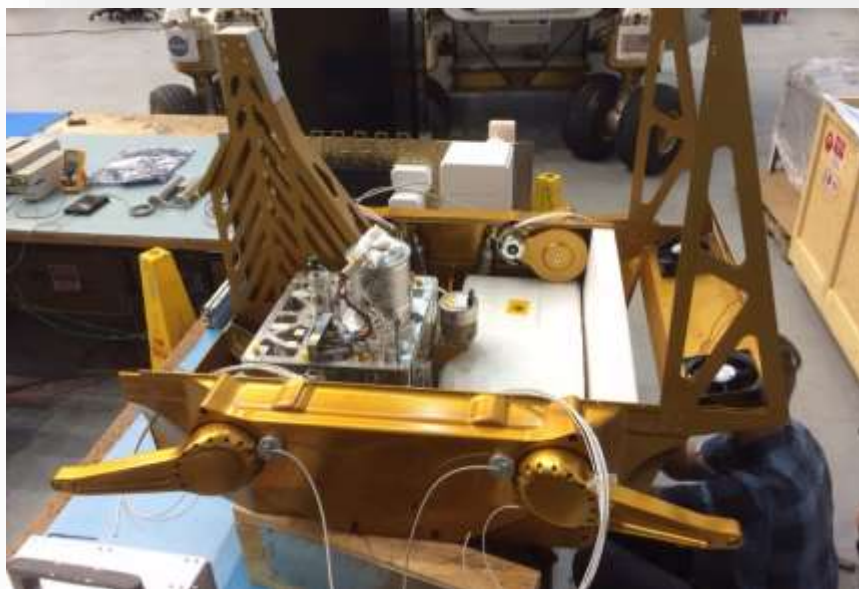
1g wheels





# RP15 Rover/Payload integration

2015-07



Rover  
Assembly



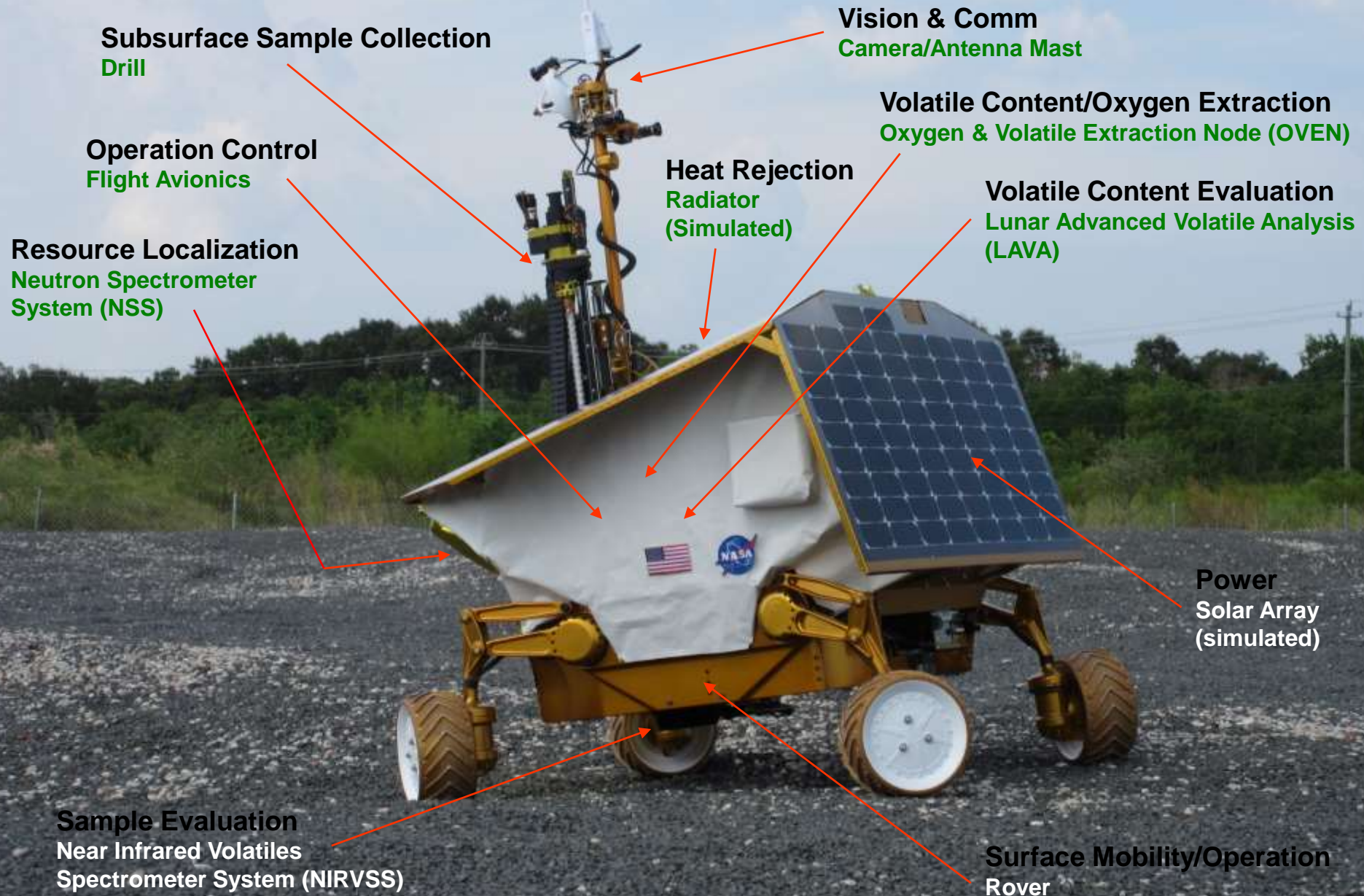


# RP15 In the Dirt

2015-08-15



# RP15: Surface Segment (Payload/Rover)



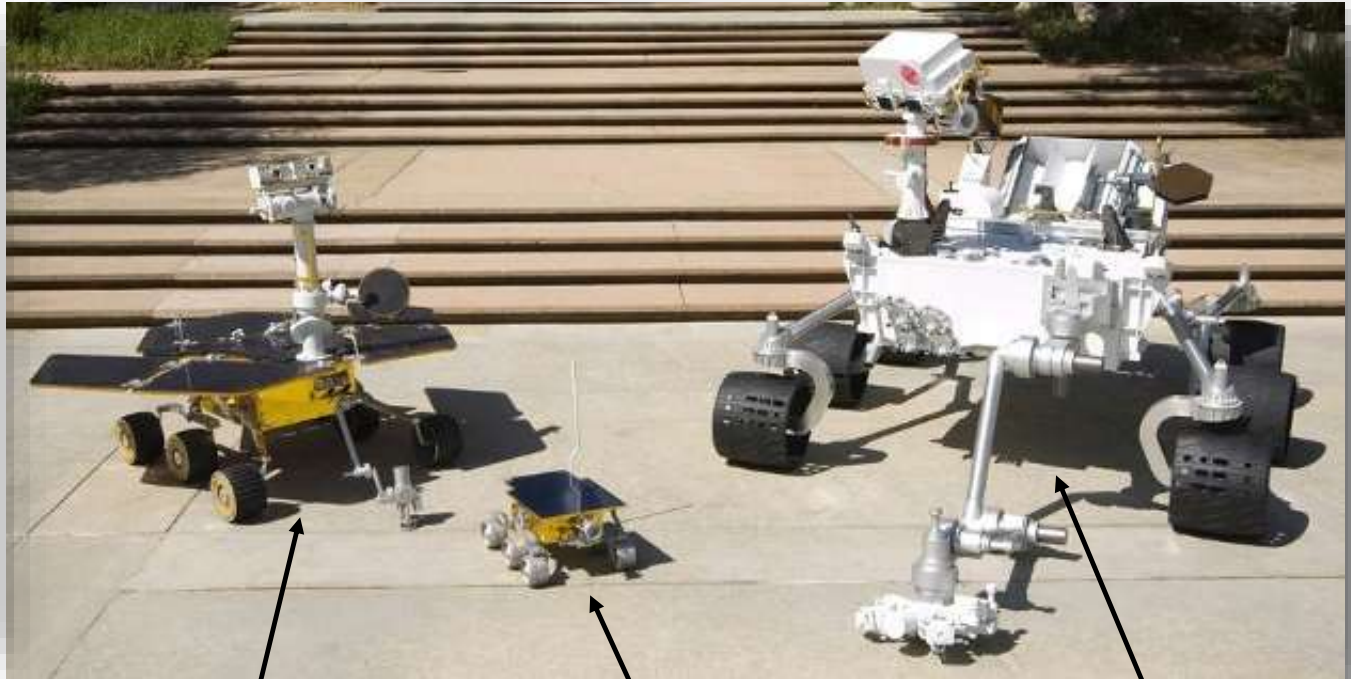


# Rover Dimensional Comparison (approx.)



## RP/RP15 (2015):

- 1.5m x 1.5m x 2.0m (LxWxH)
- Weighs about 300kg



## Spirit/Opportunity (2004):

- 1.6m x 2.3m x 1.5m (LxWxH)
- Weighs about 180kg

## Sojourner (1996):

- 0.6m x 0.5m x 0.3m (LxWxH)
- Weighs about 11kg

## Curiosity (1996):

- 3.0m x 2.8m x 2.1m (LxWxH)
- Weighs about 900kg



# RP15 First Prospecting/Processing in the Field

2015-08-18



Crucible  
awaiting sample  
inside the rover



RP15 drilling  
in the JSC  
Rock Yard



# RP15 Drilling on a slope in the Field

2015-08-24



Sloped Drilling at JSC



Sand Captured in Drill  
Brush Housing & Flutes



# RP15 Rocky Weather in Houston

2015-08-18



Mother Nature  
rebellng. Building  
sand barriers to  
flowing water

Heading back to  
the highbay to do  
a systems check



7/20/2016

Information contained in this presentation is not subject to Export Controls (ITAR/EAR)

23

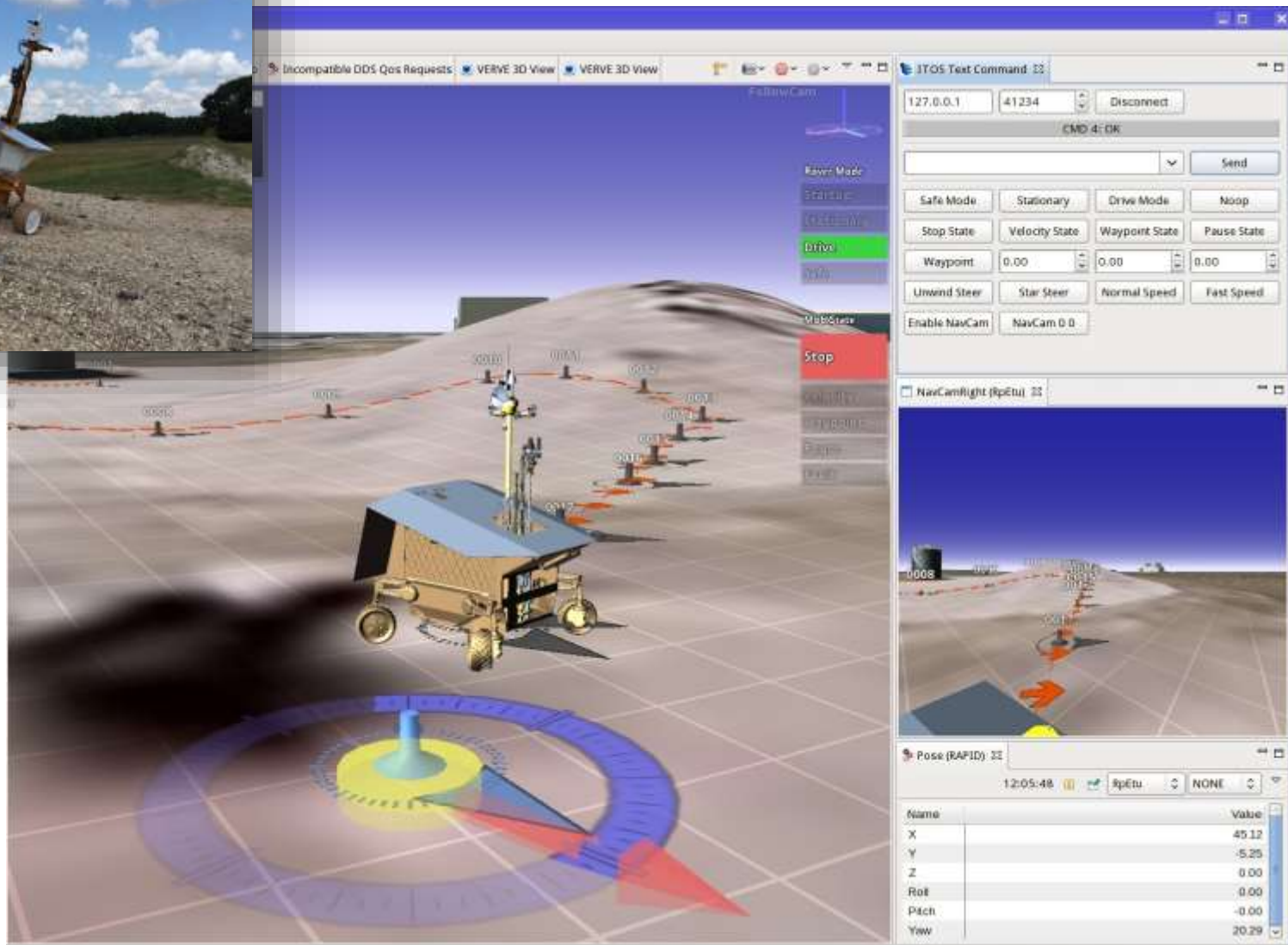
# RP15 First Prospecting/Processing in the Field

2015-08-21



**“VERVE”  
driving tool  
funded by  
STMD...**

**.... how we  
drove RP15  
at JSC from  
ARC**





# Distributed Operations Test testing

2015-08-21



NASA-ARC Mission Control room driving RP15 rover @ NASA-JSC



NASA-JSC Rock Yard from the rover (left) stereo camera



NASA-KSC Payload Control room

3-D Image Viewing of NIRVSS Camera Images During DOT



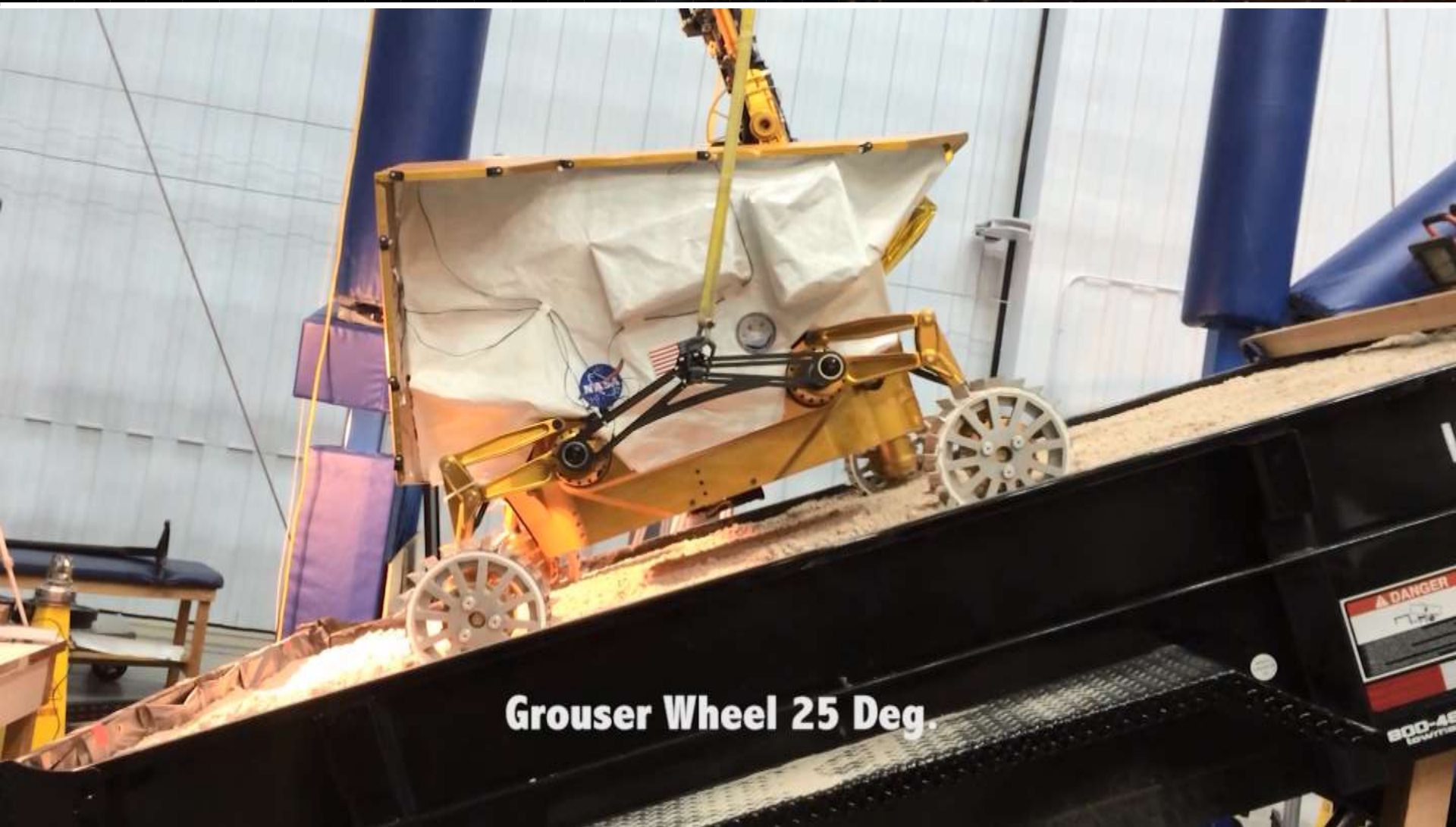


# RP15 Environmental Testing





# RP15 in ARGOS gravity offload facility (1/6g) (VIDEO)



**Grouser Wheel 25 Deg.**

Mobility, Lander Egress, Drilling

# RP15 in ARGOS gravity offload facility (1/6g) (VIDEO)



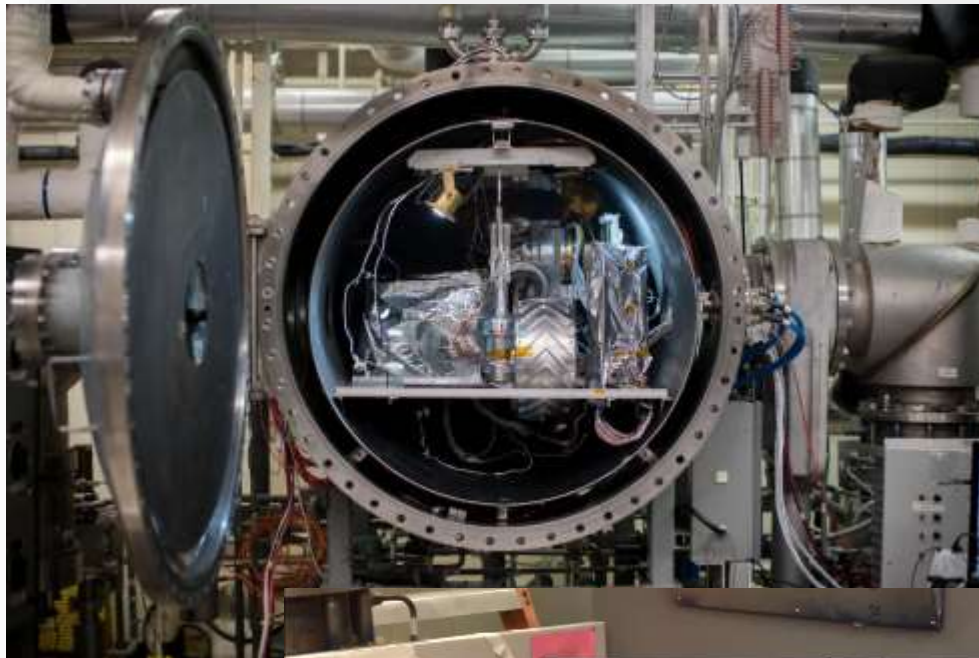
Wheel grouser studies: Obstacle climbing @ 1/6g



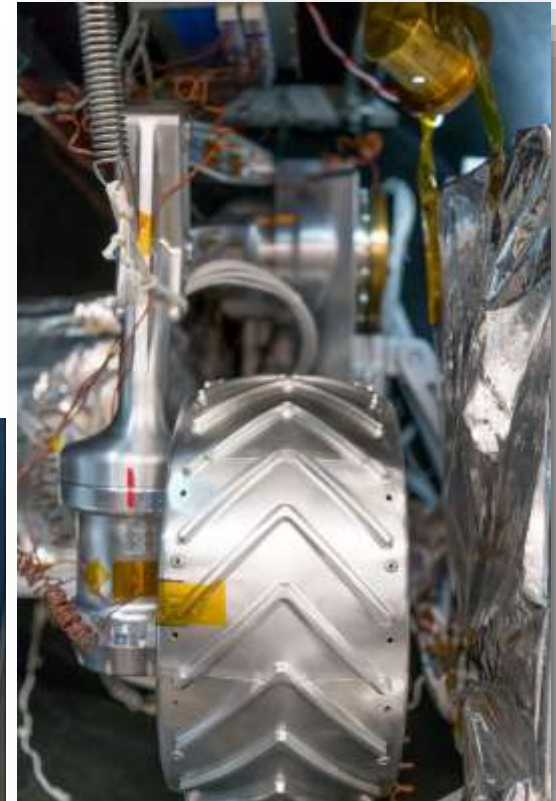


# RP15 Undergoing TVAC testing

2016-03



TVAC chamber testing of  
RP15 rover subsystems

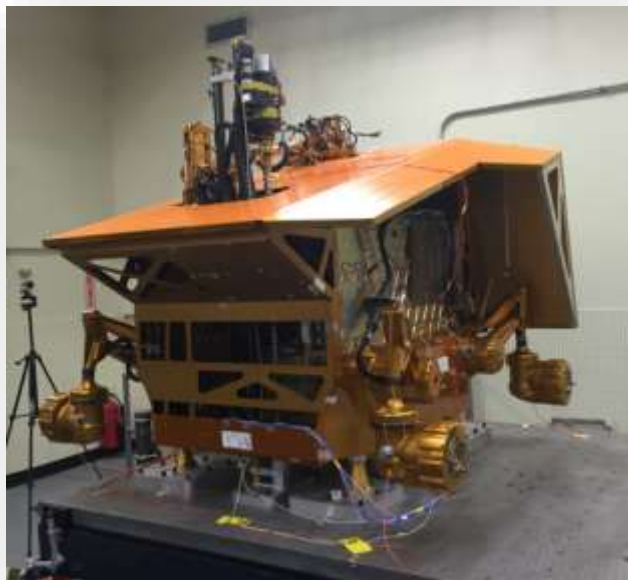


RP15 wheels & steering  
assemblies undergoing  
TVAC test



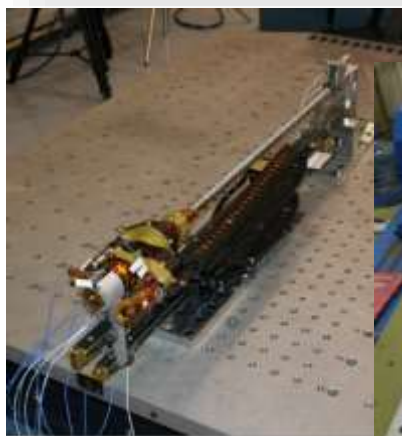
# RP15 Undergoing Vibe testing

2016-03

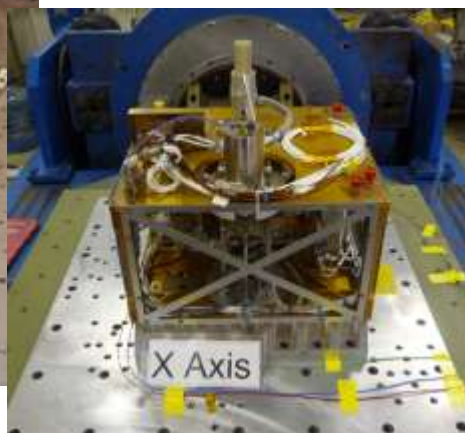


TVAC chamber X/Y-axes  
testing of RP15 rover

TVAC chamber Z-axis  
testing of RP15 rover



OVEN in vibe



Drill in vibe



# RP15 Drill testing

2016-06



Drill and sample-handling system readied for sample collection



Drill testing at NASA-GRC's VF-13 TVAC chamber measuring lunar volatiles loss when drilling a meter deep into lunar soil and transferring materials into the RP rover

Testing the flight-like RP system, including spectrometers, a drill, and sample-handling system at lunar conditions, with engineered lunar-like soil conditions, doped with 5% water and chilled to -100C

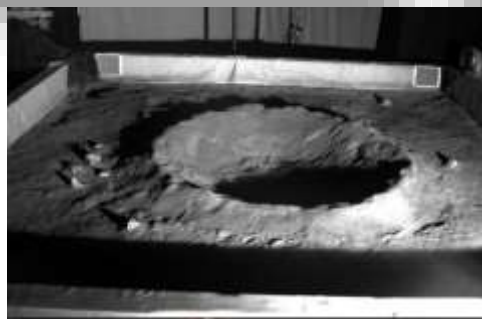
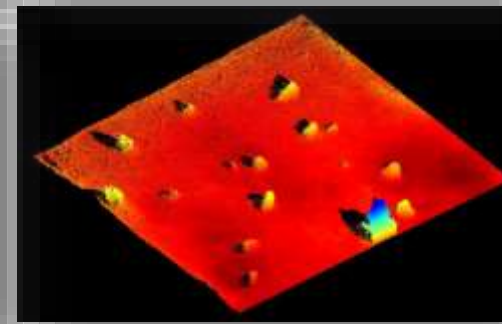
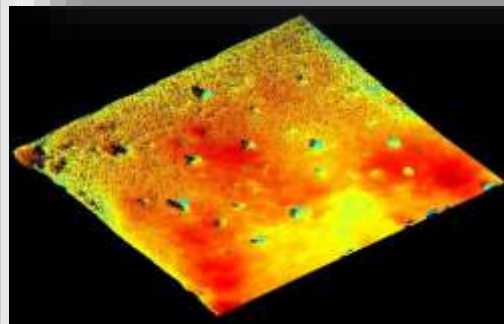
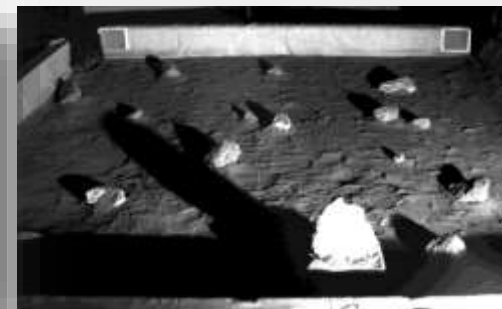
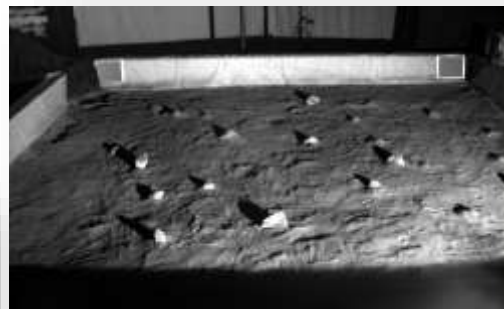
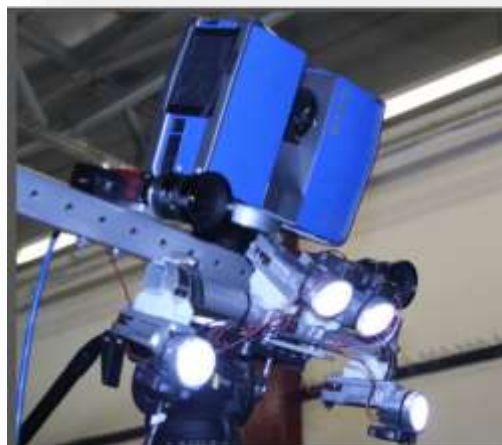


# Stereo Vision testing in lunar polar contexts

2016-06



Studying stereo camera effectiveness with different rocks sizes/distributions and low-angle sunlight (long shadows)





# RP Education and Public Outreach Activities



- Full assault on Social Media!
  - Actively putting RP's message out there
  - Ranking member Rep Mike Honda's Chief staffer requested an RP briefing @ NASA-ARC because of what he "and other techie staffers" read on Twitter

**Twitter:** NASAexplodes (@NASAexplodes) Resource Prospector rover systems undergoing thermal vacuum tests to see if they can handle life on the moon!

**Facebook:** NASA Explores Resource Prospector continues rover hardware integration for up- earth-based field tests #321TechOff

**YouTube:** Spectrum3847 (@Spectrum3847) Resource Prospector you tube link: MAXWELLERQ via @YouTube VEI @NASA

**Facebook:** NASA Explores Celebrate to Resource Prospector! The RP15 team says their 2018 goals early and under budget! One of the successful requirements was testing the 'daisy' rover. Came in at a sporty 0.45 meter/sec up and down slope!

**Graphic:** ARES June 2026 #JOURNEYTOMARS RESOURCE PROSPECTOR MISSION SUCCESSFUL HARVEST OF RESOURCES FROM THE MOON #THEMARTIAN

**YouTube:** Resource Prospector Resource Prospector (RP) is an in-situ resource utilization (ISRU) technology demonstration mission which will test extraction of oxygen, water and other vol...

# Resource Prospector (RP) Overview



## Mission:

- Characterize the nature and distribution of water/volatiles in lunar polar sub-surface materials
- Demonstrate ISRU processing of lunar regolith

## RP Specs:

- Mission Life: 6-14 earth days  
(*extended missions being studied*)
- Rover + Payload Mass: 300 kg
- Rover Comm: X-band 600kbps directional / 4kbps omni downlink
- Rover Dimensions: 1.4m x 1.4m x 2m
- Rover Power (nom): 300W
- Max speed: 25cm/s. Prospecting: 10cm/s
- Cost: <\$350M (excl LV)
- Mission Class: D-Cat III
- Launch Vehicle: Falcon 9 v1.1

## Project Timeline:

- ✓ FY14: Phase A (Formulation)
- ✓ FY15: Phase A (Demonstration: RP15)
- **FY16: Phase A (Environmental testing: RP15)**
- FY17: Phase B SRR/MDR
- FY18: PDR (Implementation)
- FY19: CDR (Critical design)
- FY20: SIR/I&T
- FY21/22: RP launch







Let's go.